DYNAMIC ADAPTIVE DAMPING ATTENUANT MECHANISM AND ENERGY RECYCLING SYSTEM ON BRAKING

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a dynamic adaptive damping attenuant mechanism and energy recycling system on braking.

2. Description of Related Art

In this work, we are focused on discovering the interconnected mechanism between the mechanical and electrical systems to make sure that the system is stable and more reliable, even the limiting load occurred. Therefore, it is called "Dynamic-adaptive damping attenuate mechanism", in short, DADAM.

Theoretically, the induced electromotive force (EF) in the magnetic field is contributed by many intrinsic properties, for example, the ratio of two coils (stator, rotor) loops, the strength of magnetic flux, the time rate of flux, and so on. In the high flux strength of magnetic filed, the magnitude of corresponding attractive force between rotor and stator is strictly high and related to the above factors. And it is referred to this as "magnetic reluctance (MR)".

We install a generator embedded into the dynamic-adaptive-damping attenuant mechanisms on this system dedicated to the braking. After the magnetization process in the magnetic coil, which for the AC generator is the wired coil on the rotor, then the magnetic reluctance force is so-called "braking effect".

For the purpose of braking, this generator is driven by the propeller on the vehicle. If the car is travelling at high speed, that means the angular velocity

of the propeller is large. At this moment, the magnetic flux rate also changes positively proportion to the angular velocity of the propeller. When a rotor magnetic field coil is provided with high flux density, it takes slight rotation or a little change in flux to produce a higher corresponding back induced electromotive force. That is, under other conditions being constantly fixed, the strength of back electromotive force changes in proportion to the rate of the flux change. Any circuit and component could be destroyed by this higher back electromotive force or huge voltage shock. Consequently, the primary limitation in the electrical-magnetic braking is the highly back induced electromotive force which results in the system to be broken down. Up to now, the most common usage is to incorporate with the voltage regulator. The magnitude of the current in magnetic coil has been repressed so as to avoid the disaster of shock. Hence, the magnetic reluctance force is also decreased which stands for the braking force is dropped off. In the sequel, the braking force faded out as for no more work.

Moreover, for another way, if using the stronger damping diodes as the damper for consuming this back electromotive force, here the temperature increases very quickly and we have to absorb the heat effectively. For removing the heat energy, the additional air or water cooling components have to be added into the braking system. In practice, there are many physical constraints to be addressed, for instance, the space to add the cooler in, the safety, and so on. Obviously, it has been brought the reasons out to use the magnetic reluctance force as the braking force is difficult to produce the actual reliable braking effect. The effective and realtime braking task is more severely troublesome.

Eventually, for example, the SCANIA bus at Taiwan, can work only just 3-5 seconds in the lower speed and very hard to keep working continuously. For the high speed case, it completely fails to carry out the braking task. After all, it has been brought the reason out why we are using the DADAM's magnetic reluctance force to produce the concrete and reliable braking effect.

Based on the concept of the energy transformation, the high speed vehicle is regarded as the vehicle with large kinetic energy. The braking that means to block the vehicle motion and the kinetic energy is transformed into the thermo or electrical energy. We need not only design an electrical magnetic device interconnected with braking system which can be protected from the shock but also allow enough high strength magnetic flux to keep this device to generate the magnetic reluctance force. As the braking occurred, we have to enlarge the current passed through the magnetic coil to generate larger magnetic reluctance force, and then induce more powerful braking force. To prevent the shock, the high back electromotive force (e.m.f) could be attenuated by somehow mechanisms internally. In common, these mechanisms are called as the dynamic damper. The alternative current generated passes through the dynamic damper. The virtual power is built in the dynamic damper and the temperature constantly increases according to the impedance change. In other words, the energy consumption is contributed by the virtual power not real power. When the temperature gets higher, the impedance is produced synchronously so that the impedance variation is related to the heat dynamically but not enough to burn down any system component. Alternatively, the impedance change affecting the dynamic buffer size follows the temperature

change.

Meanwhile, comparing the magnitude of impedance with the other external connected device, for instance, the electrical charging system, the magnitude of the internal impedance is smaller than the others. The shock is going to pass the shortcut of the electrical part of the DADAM. That is, the shock is isolated and allocated at the DADAM internally. After the shock is applied, the impedance plays a role of the fast switch for attenuating the shock. As the temperature increases, the heat source and the switching frequency (fast turning on and off) of this switch change simultaneously. In circuit of RLC, the frequency is a function of the magnitudes of inductor L, the capacitor C, and resistor R. If frequency is a variable parameter in this circuit, the value of the impedance is no longer a constant value. Totally speaking, the impedance of the system is a function of the temperature variation.

Theoretically, the notations are defined as figure 1 and referred to the book of contact mechanics [K.L. Johnson; Contact Mechanics, Cambridge University Press., 1987], the effective Young's module E* is defined as

$$\frac{1}{E*} = \frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \tag{1}$$

Also, the another parameter k_m which is called mean curvature and defined as

$$k_m = \frac{1}{2}\left(\frac{1}{R'} + \frac{1}{R''}\right) = \frac{1}{2}\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \tag{2}$$

The contact size is related to the mean contact pressure P_m and mean curvature k_m as the following

$$\alpha \propto [\frac{p_m(\frac{1}{E_1}+\frac{1}{E_2})}{(\frac{1}{R_1}+\frac{1}{R_2})}]^{1/3} = [\frac{p_m(\frac{1}{E_1}+\frac{1}{E_2})}{2k_m}]^{1/3} \tag{3}$$

or

$$P_m \propto [\frac{p\ (\frac{1}{R_1}+\frac{1}{R_2})^2}{(\frac{1}{E_1}+\frac{1}{E_2})^2}]^{1/3} = [\frac{p\ (2k_m)^2}{(\frac{1}{E_1}+\frac{1}{E_2})^2}]^{1/3}$$

Based on the Hertz's solution for the point contact, we conclude that the following properties:

1. Contact size: a

$$\mathrm{a} = (\frac{3PR}{4E^*})^{\frac{1}{3}} \tag{4}$$

2. Separation: δ

$$\delta = \frac{a^2}{R} = (\frac{9P^2}{16R(E^*)^2})^{\frac{1}{3}} \tag{5}$$

3. Maximized normal stress: p_0

$$p_0 = \frac{3P}{2\pi a^2} = (\frac{6P(E^*)^2}{\pi^3 R^2})^{\frac{1}{3}} \tag{6}$$

4. Maximized shear stress: = 0.57a

$$\tau_{\max} = 0.31 p_0 = 0.47\frac{P}{\pi a^2} = \frac{0.47P^{\frac{1}{3}}}{\pi}(\frac{4E^*}{3R})^{\frac{2}{3}} \tag{7}$$

where P is the applied total normal force, R is equal to $\frac{1}{k_m}$

5. For the tangential contact case, the β is defined as

$$\beta = \frac{1}{2}[(\frac{1-2\nu_1}{G_1}) - (\frac{1-2\nu_2}{G_2})]/[(\frac{1-\nu_1}{G_1}) + (\frac{1-\nu_2}{G_2}) \tag{8}$$

Furthermore, the absolute value of   is almost less than 0.25, this constant is strictly related to the coefficient of friction. Referred to (1), the coefficient of friction   is always smaller than $\frac{\beta}{5}$, i.e.

$$0< \ \leq \frac{\beta}{5} \tag{9}$$

If the material properties (tyres, road) G_1, G_2, v_1, v_2 and weight of the vehicle are fixed, the friction force f_r at the contact patch then never changes.

$$f_r = \ P \leq \frac{\beta P}{5} \tag{10}$$

To see more details of the dynamic behaviors of braking system, refer to the thesis [2]. By this way, see the equations (4), (5), (6) and (7), the contact size   varied with magnitude of normal force is also a constant value. That is, the braking force is almost constant value except from the numbers of tires and the weight of the vehicle increased. From the viewpoint of tribology (wear, friction and lubrication), there exists a quite obvious limitation that the braking force is not enough to block the high speed motion in the vehicle systems.

We need to perform some different kinds of design for eliminating the side effects of this bottleneck, i.e., elevating the safety of high speed vehicle and providing the basic implementation issues of the energy recycling on braking.

We are firstly claimed that the shock should be isolated and attenuated completely. In a sequel, the sharpness of kinetic energy relaxation process should not be appeared anymore. And the superabundant energy is buffered and located at the dynamic buffer zone. After the self-attenuation process in the generator, the peaceable energy can be extracted out and re-entered into the energy storage system, for example, the electrical charging system. The most important point is that smoothly and continuously working for each braking cycle is carried out. We secondly concluded that the dynamic buffer effect contributing to the energy recycling on braking is straightly worked. In the vehicle braking system, the variation of load is extremely different. If the mechanical-electrical system without any buffer or with fixed buffer zone, it is easy to be destroyed by the limiting load occurred. Again we should be emphasized on the buffer size to be regulated automatically and dynamically. It is called the adaptive buffer zone. For the time being, we can do a summary for the DADAM as the following properties:

1. Highly tolerant voltage and current.
2. Dynamic damping effect.
3. Wide bandwidth of frequency response.
4. Virtual load locating.
5. Adaptive impedance regulation.
6. No strict gradient of temperature.
7. Low cost.
8. Dynamic buffer size generating.
9. No extraneous power consumption.

10. Self attenuation without second shock generation.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view showing the notation definition;

Fig. 2 is a schematic view for the internal equivalent circuit of electrical part of the DADAM;

Fig. 3 is a schematic view of a generic AC generator;

Fig. 4 is a schematic view of the principle of the DADAM embedded into the generator;

Fig. 5 is a schematic view of the complete electric-magnetic auxiliary braking and energy recycling system;

Fig. 6 is a schematic view showing the magnetic coil in the DADAM's AC generator;

Fig. 7 is a schematic view showing the internal (Zi) and external (Z_{out}) impedances distribution; and

Fig. 8 is a schematic view showing the shock V1, V2, and V3 occurred in the DADAM's AC generator.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

2. Implementation

As shown in Fig. 2, the structure of electrical part of DADAM can be simply sketched, where p_1 and p_2 are the procedure to input pins, and the component thermopile plays a role of the positive (negative) thermo effect.

Of course, the magnitudes of the varied resistor (VR), varied capacitor (VC), varied inductance (VI), varied attenuator (VA) are dependent on the loads and the impedance of the other connected devices respectively.

And the thermopile plays a nominal role of fast switch and follows the temperature when it changes. For the positive type, as the shock comes, the temperature is getting high; the correspondence impedance becomes a proportionately large value. After the shock is removed, the temperature is going down; the impedance also returns to the nominal area and waits for the next cycle to come. In the transition process, how fast the switch works on is dependent on the natural frequency of material, i.e., what kind of material made. The bandwidth of frequency response, under 10.0 GHz, is now capable of using and more strictly related to the realistic implementation issues (for example, SiGe, GaAs, InP,...). If the gradient of temperature is positive (negative), the frequency of switching should be speeded up (slowed down) and transit into some kind of equivalent state between temperature change and impedance increase (decrease). When the shock coming, the impedance (contributed from the electrical part of DADAM) has been self-tuning more and more again and adaptively going back to the temperature-impedance steadily state. The VR, VC, VI, VA are dynamically determined from the magnitude of shock input and finally produced an equivalent state internally.

The original three-phase AC generator is as shown in Fig. 3. The difference of phase angles between $_1$ and $_2$, $_2$ and $_3$ or $_3$ and $_1$ is 2/3.

When DADAM has been embedded into 3-phase AC generator, the system is modified as shown in Fig. 4.

The primary difference between the original and modified AC generators G has been mounted on the DADAM components Z_1, Z_2 and Z_3 dynamical impedance as that shows in Fig. 4, Z_m is the avoidance of the second

high induced e.m.f. for the input of the magnetic coil damage. In the same time, they lead high induced e.m.f. into the stator (Z_1, Z_2 and Z_3) and rotor (Z_m) and induce that self attenuation process to re-start up again and again. Take notice that the numbers of the dynamical impedances are equal to the numbers of phases of the stator. Again, the magnitude of all of dynamical impedance is dependant on the real problems requirement and determined dynamically.

Finally, we are presented the complete energy recycling and electric-magnetic auxiliary braking system as shown in Fig. 5.

In Fig. 5, we have add six generators G_0, G_1, G_2, G_3, G_4 and G_5 to be embedded into the DADAM, where G_0 is driven by power source (engine), G_1, G_2, G_3, G_4 are driven by the four wheels (Front-Right, Front-left, Back-Right, Back-Left sides respectively. Without loss of direction on braking concentrating, G_5 is the primary DADAM type generator driven by the propeller for the auxiliary braking and energy recycling on braking. We are able to increase the numbers of generator for the heavy load case.

In order to avoid over charging problem, incorporating the circuit of the UPS (Un-interruptible Power Supply) in this area can help us to switch which battery (A or B) to store recycling electrical energy in realtime.

The principle of the DADAM

The working principles of the DADAM are concluded as the followings:

1. as shown in figure 6, SW1 on, the current Im passes through the magnetic coil with inducant Lm and then the flux B built up. The strength of the flux is proportional to the product of the current and loops of the coil,

$B \propto I_m N_m$

the value of the impedance is Zm and Z'm simultaneously. Also, as shown in Fig. 7, the DADAM's electrical-magnetic braking system now is working on. When enlarging the input current Im, the braking effect is enhanced. To this end, the impedance Z_1 is always slightly smaller than the outer impedance Z_{out} so that I_{out} is smaller than the current I_i. Because the electrical parts of the DADAM's braking system are the temperature dependent, the current passed through Z_1, Z_2, Z_3 and the switching frequency is moving to high. Comparing the internal impedance Z_i with $Z_{out,}$, Z_i is totally smaller than the Z_{out}. Here the Z_i is a fast switch. When this switch is on, Z_i is a shortcut for the shock. On the contrary, when this switch is off, the shock is going to fan out. At the same time, the switch changes the status on, the shortcut effect is triggered on. The status switching is working again and again. For the fast on and off status switching, the shock is firmly isolated and stays at the Z_i.

2. At the shock V_1, V_2, V_3 occurred, as shown in Fig. 8, the high temperature built up and the gradient of temperature is fed into the stator coil of the DADAM's AC generator and then determining the value of the impedance and the switch frequency. At the kinetic energy transferred to the electrical energy process, the least thermo energy is converted to the on and off actions and regulating the magnitude of the impedance. The superabundant energy is cycling on the DADAM's electrical-magnetic braking system only, no any

energy loss. This is a dynamic damper effect. The shock is attenuated by this dynamic damper.

3. If designing the value of Z_i is always dynamically smaller than the Z_{out}, firstly the shock is directly across the Z_i. at the original state (0-state), the current I_i^0 is firstly passed through and the high temperature field is then built, the magnitude of impedance Z_i becomes a large valve and the state of Z_i has changed to 1-state (high temperature status), the current I_i^1 becomes a smaller value than I_i^0. In fact, once the electrical energy is led out to the charging system immediately and the temperature is getting down. As the temperature gradient being a negative value, the status (1-state) right now changes to the original status (0-state), without any current across Z_{out}. The state changes between the 0-state and 1-state are no stop until the shock removed. We denote these states transition with a very wide operating frequency band. After all, the shock produced on braking is recycled.
4. From the shock isolation, attenuation and finally recycling to the electrical charging system, all of them are dynamic and adaptive self-balancing processes. It is truly without any digital or analog controller add-on.

It is to be understood, however, that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosure is illustrative only, and changes may be made in detail,

especially in matters of shape, size, and arrangement of parts within the principles of the invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.